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SOME OBSERVATIONS ON THE FORMATION OF THE CAPILLITIUM AND THE DEVELOPMENT OF PHYSARELLA MIRABILIS PECK AND STEMONITIS FUSCA ROTH[1]

G. R. Bisby

WITH PLATE XXIV

While examining preparations of *Physarella mirabilis* with a view to a study of nuclear phenomena, certain observations were made on the development of the capillitial threads so numerous in this species. In view of the fact that Physarella has not heretofore been studied cytologically; and, further, since the formation of the so-called solid capillitium is still a matter of discussion, it seems worth while to publish at this time the results so far obtained. While the study was in progress, some fruiting specimens of *Stemonitis fusca* were secured, from which supplementary data were obtained.

The literature pertaining to the capillitia of Myxomycetes has been carefully summed up by Harper ('00, '14*b*) and by Harper and Dodge ('14*a*), so that it is unnecessary to give here more than a brief glance at earlier investigations. Harper, in his papers on the subject, has described thoroughly the formation of capillitium in certain species in which it is distinctly hollow, and was able to corroborate and add much to Strasburger's ('84) earlier account of the process of formation. In his paper on cleavage in a recent issue of this Journal, Harper gives incidentally some data regarding the capillitium of *Didymium melanospermum*, but does not dwell upon the methods of its formation.

MATERIALS AND METHODS

Pieces of well rotted wood were collected in Prospect Park, Brooklyn, in November, 1913, and placed in covered battery jars. Upon this wood developed several species of Myxomycetes, the plasmodia of Physarella being especially abundant. Sporangia in large numbers were formed repeatedly, yet sufficient vegetative plasmodia usually remained to continue the culture. These developing sporangia were fixed in various stages of development in the Flemming-Strasburger medium solution, and stained principally with Flemming's triple stain.

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[1] Brooklyn Botanic Garden Contributions, No. 8.

The development of sporangia in cultures usually began during the afternoon and was completed by the following morning. Some little variation was observed as to the hour of maturity of certain fruiting groups, due possibly to somewhat unusual conditions of light, heat, or moisture. It was curious, however, to note that the various forming sporangia of a group developed almost simultaneously, in spite of the fact that all connection between them was early lost, and that some were at the edge of the water in the bottom of the jar, while others were formed on higher and apparently much drier portions of the wood. Mature sporangia were, however, perfectly normal in any case.

CAPILLITIUM FORMATION IN PHYSARELLA MIRABILIS

A mature sporangium (see figure 15) in this species contains a large number of more or less branched capillitial threads radially arranged. These threads are smooth, except for an occasional small spinous projection, and at first glance appear solid, except where they broaden out to constitute a lime knot. These knots are numerous, and vary in size from that of a barely perceptible swelling in a capillitial thread, to large spicules extending from side to side of the sporangium.

When the plasmodium first begins to form lumps where sporangia are to occur, the protoplasm presents no essentially different appearance from that of the vegetative stage, save that much of the extraneous substances has been extruded and left along the somewhat slimy trail; the same bubbly appearance is presented. Before long, however, spaces appear in the protoplasm, into which waste substances, largely lime granules, are excreted. In sections of the protoplasm as it becomes more finely granular, fine tubes can be detected, sometimes connecting the knot spaces with the exterior, and sometimes without any perceptible attachment to a developing lime knot. The membrane surrounding the tubular opening is continuous with the membrane surrounding a knot space, if any of the latter be in connection with this opening.

Such a condition is shown in figure 1; the lime knot and capillary tubules connected with it are bounded only by a plasma membrane continuous with the membrane at the external surface of the protoplasm. In this figure the protoplasm has shrunken slightly away from the sporangium wall. This shrinkage is undoubtedly artificial. The lime knot is nearly filled with cystolithic granules of calcium carbonate; in this instance, the acids of the fixative apparently did not penetrate sufficiently to dissolve out the lime. In the figures following (figures 2–4, 11) representing succeeding stages, the calcium carbonate appears to have been largely removed and only a small amount of substance remains in the lime knots. In young stages, the tubular spaces which extend through the protoplasm and which define the location of future capillitial threads, usually appear empty and are rendered visible only by very careful focusing. They are usually of a very narrow diameter; most of the mature threads, for that matter, are also much attenuated. The capillitial space in the center of figure 1 is, however, slightly wider than usual and contains some stainable substance, possibly lime. The sporangial wall in this and certain other figures presents an altered appearance due to the removal of the lime naturally present. Two aggregations are shown, however, in the wall of figure 1 which are interpreted as areas in which lime has been present.

Figure 2 represents a somewhat later stage of capillitium formation. The protoplasm is seen to be in contact with the forming thread, a plasma membrane being evident only where the lime knot, from which the contents have been largely dissolved, has shrunken away. The sporangial wall in this figure is rather thick, and its inner surface is in direct continuity with the walls of the thread, while the thread itself is in turn continuous with the walls of the lime knot. This capillitial thread in figure 2 is clearly hollow save for an attenuated portion near the periphery of the sporangium, where no lumen is evident.

The threads are by no means all formed simultaneously. Spaces without deposition may be found in sections showing capillitial threads which are nearly mature.

Figure 3 shows similarly the continuity of the thickened walls of the lime knot and those of the threads. In this case a more advanced stage is figured, for the bounding walls are much thicker than in the previous figure. Shrinkage of the lime knot has not occurred, although its contents have been largely removed.

In figure 4 the hollowness of the narrow thread is not apparent. Here is shown further the connection of the capillitial threads and the lime knots, as well as a branching thread. Figure 5, from an older sporangium, shows again the connection of thread and exterior. The hollow nature of the thread is here again plainly apparent where it widens out slightly. In this figure the protoplasm appears not at all shrunken, being in intimate contact with both capillitial thread and sporangial wall.

Figure 6 represents a small section of material collected in the morning shortly before the time of complete maturity of the sporangia. In some sporangia of the collection at this hour, cleavage had progressed to a considerable extent; while in the majority of cases cleavage is not so evident, the protoplasm being still in close contact with the thread, in the manner shown in the figure. Figure 7 does indeed indicate a case at this stage in which there is a slight space between the thread and the plasma membrane, and similar cases may in fact be found at other stages. I have interpreted such cases, when occurring at some time prior to cleavage, as arising from a slight shrinkage of the protoplasm away from the threads, due probably to fixation. At any rate, this earlier shrinkage should be clearly distinguished from the normal cleavage furrows which later follow the capillitial threads and which have been interpreted below as normal occurrences. The nuclei present an interesting appearance at this stage for, as is shown by one in figure 6, many are surrounded by a vacuole-like space. Harper points out ('14*b*, p. 133) this same phenomenon in Didymium; and interprets it as "hardly due to shrinkage in fixation, since they are scattered among other nuclei which show no such peculiarity."

Capillitium in Relation to Cleavage in Physarella

Although the threads may be found in contact with the cytoplasm until a short time prior to cleavage, at the first suggestion of that phenomenon there is no doubt but that this contact ceases to exist. Harper has elaborated this point in his Didymium paper. Figure 8 shows an early stage of cleavage, in which every forming furrow is plainly associated with one or more capillitial threads, which appear in cross or oblique section in the preparation. The threads all appear to be hollow; that this appearance is not an artifact is attested by numerous observations on other material. At the upper right in figure 8 is a thread which has not yet been surrounded by a cleavage furrow. However, a slight space, as is commonly found at this stage, surrounds the thread. Conditions in the left part of figure 8 portray a slightly more advanced state in that the cleavage furrows are of a greater diameter. Near the center of this figure cleavage has not actually been instituted, but the cytoplasm presents a more hyaline appearance, suggesting very clearly that cleavage in this place is about to result.

In figure 9 is represented a stage of cleavage slightly more advanced, in which the nuclei are in the equatorial plate stage of division, and each is surrounded by a hyaline space. The longitudinal view of the thread in this figure shows plainly its hollow nature. The manner in which cleavage furrows follow the threads is suggested by this figure, although it is difficult to picture the irregular fissures passing as they do at right angles to the axes of the capillitial threads, as well as up and down them.

Figure 10 shows a still later stage in cleavage. The large piece of spore-plasm shown in the figure is bounded here and there by capillitial threads in close proximity. Many of the threads lie, in fact, in bays or deep indentations of the protoplasmic mass, suggesting their intimate association with the inauguration of the cleavage furrows. A shrunken lime knot is represented in cross-section at the upper left part of the figure.

Figure 11, from a nearly mature sporangium, shows again the continuity of the inner portion of the sporangial wall and the exterior boundary of a larger lime knot, cut somewhat diagonally. The lime contents of both knot and wall have been largely removed by the action of the fixative.

Figure 12 was drawn from a mature sporangium crushed in a drop of water on the slide. It shows a mature thread, plainly hollow and not solid, as might be supposed from a hasty examination, of somewhat varying diameter, and two lime knots, the larger of which is small compared with the size of an average knot. A spore is shown adjacent for comparison of size. Within the knot, as is in fact always the case in Physarella, are many granules of calcium carbonate, rather uniform in size and shape. When these are dissolved in acetic acid, the knot presents the same essential appearance as it does in sections of fixed material.

Figure 13 represents a mature capillitial thread. As is shown, branching occurs; while the surface is smooth save for the "spines" occasionally present. This thread is hollow, as is represented in the figure, but this condition is by no means clearly apparent in every mature capillitial thread. Chloroiodide of zinc solution, with which they stain yellow, often serves to bring out more clearly the hollowness of these threads.

Figure 14 is another preparation from a mature sporangium, the figure being a surface view of a portion of the sporangial wall. A small but definite area is shown densely charged with lime granules, while in the surrounding wall are embedded more or less isolated lime granules. The larger lime knot undoubtedly corresponds to the knots shown in section in figures 1 and 11. The darker spots in figure 14 represent aggregations of yellow coloring matter. It may be noted here that the plasmodia of *Physarella mirabilis* are bright yellow; the hollow stalk of the mature sporangium is reddish; while the spore bearing portions are, to the naked eye, grayish-yellow. Each lime granule in a knot or in the sporangial wall has also a yellowish tinge, and this color seems to dissolve out in water, leaving the granules nearly colorless after a time. The capillitial threads also have a yellowish cast when viewed under the microscope.

Figure 15 is a partially diagrammatic drawing of three-fourths of one of the mature, somewhat funnel-formed sporangia, on its hollow, cylindrical stalk, showing the relation of the various parts.

THE CAPILLITIUM OF STEMONITIS FUSCA

While the work on Physarella was in progress, fruiting material of *Stemonitis fusca* was collected from one of the cultures. It was not long after the emergence of the white plasmodium from the interior of the wood, that a heaping up of the protoplasm occurred, defining the sporangial groups. Complete development from the first appearance until maturity occupied only the twelve hours from noon to midnight. About two hours after the sporangia in the fruiting groups had attained their typical size and shape, the brown tint of maturity was apparent.

The classical example of the so-called solid capillitium is that of Stemonitis. The arrangement of the intricate system of capillitial threads in this species is a familiar picture. The hollow stalk continues as a central columella to the very summit of the sporangium. From this columella branches off at right angles a profuse system of rather coarse, branching threads, which terminate sub-peripherally just within the fragile, often evanescent sporangial wall in a delicate, anastomosing, capillitial sac.

In longitudinal sections of very young stages, the hollow stalk is seen extending as a comparatively large, cylindrical cavity from the very base of the fruit body up to near its summit. The plasma membrane surrounding this central cavity secretes the hollow stalk up which the protoplasm climbs to form finally the sporangium along its upper portion. Figure 16 shows in median section the upper portion of such a central axis, cut somewhat obliquely. At its very apex, the irregular and rather tubular space in which the columella is formed appears broader than it is below, where deposition of wall substance has begun. In the lower part of figure 16 the somewhat shrunken and diagonally cut columella has attained some degree of thickness from deposition of wall substance from the plasma membrane. Into the upper portion of this space may be noted the intrusion of finger-like processes of protoplasm, while some irregular masses of protoplasm lie detached within the cavity itself. Indeed, one quite commonly notes in sections the presence of protoplasmic masses inside the columellar cavity, even in much older stages. The figure illustrates quite clearly just how their presence in such situations is to be explained, arising as they do from fragments detached from above by the ever advancing columellar apex. This point will be considered in some detail in the general discussion which follows.

Just above the apex of the cavity in which the stalk is being formed is seen the much vacuolated protoplasm which marks the region into which the columella is soon to advance. Denser areas lie still further beyond; while still other dense areas are shown at the sides of the upper portion of the space. Extending upward at a slight angle from the rising columellar cavity may be noted a tubular space. Careful focusing at this part of the preparation reveals in fact a profusion of such narrow spaces, radiating in an upward direction from the apex of the large cavity and extending in some cases even to the periphery of the mass of protoplasm. Occasionally it can be seen that such tubular spaces are directly connected with the main large columellar cavity, the plasma membrane of the one being continuous with that of the other.

Forming capillitial threads may be noted in quite an early stage of the sporangium. Not, however, until the structure had assumed its final form, in the fruiting material studied, were the capillitial threads observed in any abundance. The method of deposit of capillitium in *Stemonitis fusca* appears to be in entire agreement with the process as found in Physarella. Figure 17 shows an early stage in which the tubular space in the still foamy protoplasm is bounded only by a thin membrane, no wall deposit being as yet apparent. I have not attempted to show in great detail the various degrees of thickening of these developing threads, instances of which are rather common in the preparations. Figures 18, 19 and 20 show this phenomenon incidentally, and perhaps as convincingly as a more detailed series of drawings would.

Figure 18 represents the attachment of a capillitial thread to the columella. The thread has here attained some thickness, as may be observed further away from the central columella where the thread widens somewhat. At this wider portion the wall appears somewhat wrinkled or irregular. Near the columella the thread is of sufficient degree of attenuation to obscure the lumen. The protoplasm in this instance is in close contact with the thread. The expanded attachment of the capillitial thread to the columella is of some interest, since it is evident that the broader attachment is a continuation of the outer portion of the thickened central columella. So far as my own observations have gone, I have not found the lumen of the columella to be continuous with the lumen of the capillitial thread, which point is in agreement with De Bary's findings.

Figure 19 shows a cross section of material in a similar condition; here, however, the protoplasm has been shrunken away from the thread and half the columella, possibly by the initiation of cleavage. Within the columella may be noted the presence of some stainable substance, probably protoplasm.

Figure 20 represents a case in which cleavage is just beginning from the surface of the sporangium. The nuclei are in the equatorial plate stage, and the protoplasm is distinctly more finely granular and richly stainable at the periphery, perhaps due, as Harper suggests, to contraction of sporeplasm and extrusion of water. As is shown in the figure, the reticulations that form the net-like capillitial sac of the mature sporangium have been already formed just within the outermost portions of the protoplasm. Deeper down within the more foamy protoplasm the threads are still, in some cases, clearly in contact with the cytoplasm. In most cases in this preparation it was clearly evident that the threads are of a hollow nature. Although any relation to cleavage is not definitely shown in this figure, it is apparent from a study of the sections that here also the cleavage furrows are influenced and defined to a considerable degree by the capillitial threads, just as in Physarella.

As is well known, the sporangial wall in Stemonitis is very fragile and eventually disappears. In younger stages it may be noted as a thin bounding membrane; while from older or mature sporangia it is usually missing. In figure 21, from a preparation similar to the one from which figure 20 was drawn, this outer wall is shown, broken and removed from contact with the protoplasm. A very delicate, connecting capillitial thread is to be seen in figure 21, its attachment to the sporangial wall quite comparable to that already examined in Physarella.

Figure 22 is a high power drawing of a mesh of the inner portion of the mature dried capillitium. As is indicated by the dotted line, a portion is clearly hollow; while other parts, due to their dark color and narrow diameter, did not present an appearance that could render possible a statement that they were hollow. Of course an appearance simulating hollowness can easily be obtained if a thread is slightly out of focus. There is, however, no doubt but that, though the lumen may be at times extremely capillary, the most of these threads are really hollow; a focus on a bent "knee" of an anastomosing thread, for example, often clearly demonstrates this point.

General Discussion

The term "vacuoles," as applying to the openings in which the capillitial threads are to develop, would seem to be misleading in the case of the two species under discussion, since these openings in question appear to be quite commonly, if not indeed invariably, invaginations from the sporangial surface, or from the plasma membrane bounding the columella. It is of course quite likely that these more or less tubular openings in the protoplasm are due to some tensions arising in the viscid mass; the fundamental causes resulting in this and related phenomena are, however, obscure. Much easier to understand, it seems to the writer, is the process of deposition of the fine, smooth capillitial threads.

Taking first the case of *Physarella mirabilis*, tubular capillary spaces appear in early stages of sporangial development. These spaces are no doubt filled at their beginning with watery sap and aqueous waste, connected as they are with lime-knot spaces and opening upon the developing outer membrane. From the plasma membrane surrounding these capillitial primordia, wall substances are next secreted. I am as yet unable to state positively whether the thin wall deposited early in capillitium formation is folded or actually pushed inward by subsequent external deposits from the surrounding plasma membrane; or whether the tubular cavity gradually increases in size, deposition thus resulting in a constantly increased total diameter of the capillitial threads. I am inclined to think that the former process obtains to a certain extent and that actual diminution in size of the lumen of the capillary tubules sometimes consequently results. The substance secreted to form the walls of these hollow threads is presumably plastic for some little time after formation. Furthermore, there may undoubtedly occur a wrinkling or folding of the thread during the process of drying, particularly in regions where it is comparatively broad. This latter appearance is more frequent in *Stemonitis fusca*. However, in any case, as has been previously stated, there can very frequently be observed within the thread a lumen of greater or lesser diameter. I know of no good reason why practical solidity should not occur in certain cases; such, for example, as would result from a deposit in a tubular space of extremely capillary proportions.

It is further shown beyond doubt in the case of Physarella the same method of deposit obtains in the formation of walls about both lime knots and capillitial threads, as that seen in the formation of the inner part at least of the sporangial wall. The first few figures show clearly the continuity of the boundary of those parts. Although the external surface of the outer peridium appears thicker, presumably from hardening through exposure to the air, I have no doubt but that the whole sporangial wall is of similar character and deposited by protoplasmic secretion.

The large amount of lime in the mature sporangium of Physarella suggests an approach to the condition obtaining in *Fuligo varians* in regard to the amount of lime present. The old analysis of Reinke and Rodewald ('81) credits that species of Fuligo with 27.7 per cent of calcium carbonate, and 5.33 per cent of calcium in combination with higher fatty acids. The absorption, deposition, etc., of this calcium carbonate in these Myxomycetes furnishes an interesting problem, since, as is well known, $CaCO_3$ is soluble only in 100,000 times its own weight of pure water. It is further curious that some species should provide themselves with such large quantities of calcium carbonate, while others apparently lack it entirely.

The formation of the columella in *Stemonitis fusca* takes place by means of a progressive deposition of wall material along a cylindrical space that reaches from the base of the young fructification upward through the rising mass of protoplasm. The irregular radiations and extensions of the apical part of this space resembles somewhat the condition as figured by De Bary ('87) for *Stemonitis ferruginea* (p. 432, figure 186, a) in which the upper portion of the columella is pictured as frayed out in a brush-like fashion. The exceedingly vacuolar appearance of the protoplasm above the columellar space (see figure 16) suggests both the rapid pushing up of slender, tubular invaginations from the apex of the space itself, as well as the final incorporation into the columellar space of the vacuoles that lie in its upward path.

It has already been pointed out that some protoplasm is regularly left within the columellar space, cut off from the mass above the columella by the upward pushing, slender invaginations and vacuolar cavities which are characteristic of this area apically from the tube. In younger stages of columella formation, the protoplasm included in its hollow interior shows some evidences of continued activity, although often broken up into very small, rounded fragments. In older stages, however, its appearance suggests a much less active condition; and it probably ultimately dies.

In Stemonitis the same essential phenomena in regard to capillium formation undoubtedly obtain as those described above for Physarella. Views of early stages of the spaces in which are to be secreted the capillitial threads show an appearance of considerable irregularity and anastomosis, and they are with difficulty traced through the foamy protoplasm (figure 17). Later stages show the threads with more or less thickening deposited adjacent to the plasma membrane. Ordinarily, careful focusing on thin sections reveals clearly the tubular character of these threads. The attachment of capillitial threads to the central columella displays a condition somewhat comparable to the attachment to the sporangium wall in the case of Physarella. It is noteworthy in Stemonitis that the threads are evidently in connection with the exterior deposition upon the columella, pointing to the fact that the threads are formed by a deposition no different from that which forms the columella; nor indeed from the wall deposit itself, as figure 21 evidences. The further fact that in the cases figured (figures 18 and 19), the lumen of the thread is not continuous with the lumen of the hollow columella shows that in these instances at least, the capillitial cavities were started to be formed some time after the columella wall deposit had attained some degree of thickness. If the capillitial tubules should begin to form as early as columella deposit, the lumen of the two should undoubtedly be continuous.

The formation of the reticulated, capillitial sac just within the exterior protoplasm of Stemonitis is at first glance a puzzling phenomenon. This would obviously result in a layer of spores being formed outside the main capillitial network; in fact, a careful examination of a fresh, mature sporangium shows that such is indeed the case. It is evident that this rich development of a layer of capillitial threads just within the peripheral protoplasm must result from a very rapid secretion of wall substances from the rapidly maturing external protoplasm. Only comparatively few of the very delicate threads which connect this anastomosing network with the external wall apparently have an opportunity to form, so quick are these changes in the peripheral portion of the sporangium.

Contrasting the sporangial walls of the two species under discussion, it seems clear that the thickness of wall deposit must depend to some extent upon the length of time the peripheral protoplasm remains in a relatively quiescent state. In Physarella, external secretion apparently continues during a considerable portion of the time of development of the sporangia. In Stemonitis, on the other hand, cleavage begins at the exterior very shortly after the heaping protoplasm attains its final shape, and in consequence the sporangial wall reaches only a meager development.

Some mature capillitial threads in *Stemonitis fusca* are somewhat flattened; some are somewhat irregular in shape, especially at the meshes; some present a wrinkled or crumpled appearance, as before mentioned. In some cases the occurrence of solidity is hard to disprove; but studies of many sections and of mature capillitia indicate without any doubt that hollowness of the threads is in reality very common.

The smoothness of the exterior of the capillitial threads in both species studied is in striking contrast to the spirally thickened and otherwise marked, distinctly hollow threads of certain other Myxomycetes, such, for example, as Trichia. But in the essential features of the process, the phenomena connected with the formation of the two types of threads are regarded as entirely similar, consisting in both cases in the deposition of hollow threads by plasma membranes lining tubular capillary spaces. In Trichia, however, the capillitial cavities are of relatively large diameter; while in the two species described in this paper, they are of very narrow diameter. The fact that in Trichia and similar cases, the capillitium starts in vacuoles in the interior of the protoplasm, while in Stemonitis and Physarella these spaces apparently originate as invaginations of the external plasma membrane or that lining the capillitial or columellar cavities, is undoubtedly of fundamental importance.

Cleavage in these two forms under consideration is decidedly progressive. This shows particularly strikingly in cross sections of young sporangia of Stemonitis, in which cleavage will often be seen to involve at one time only a small sector of the peripheral protoplasm. I am unable, however, to add anything new to the valuable observations made along these lines by Professor Harper ('00, '14*b*).

I am indebted to Dr. Olive, under whose supervision this work was carried on, for suggestions and criticisms freely given during the course of these investigations.

SUMMARY

1. The capillitium of *Physarella mirabilis* and of *Stemonitis fusca* is formed within tubular capillary spaces. In both cases these spaces are formed as invaginations into the protoplasm, and are not considered to be vacuoles. From the plasma membrane lining the tubular spaces occurs a progressive deposition of substance to form the walls of the capillitial threads. This deposit is continuous with that forming the sporangial wall; and, in Stemonitis, as well with that which forms the columella wall, to which the radiating, tubular threads are attached. In Physarella, a continuous wall also exists, bounding capillitial threads and lime knots, when they are in connection with each other.

2. The protoplasm remains in contact with the capillitial threads until a short time prior to cleavage. Cleavage furrows then appear, which follow the threads and which are thus determined to some extent by the capillitium.

3. The mature capillitial threads of these two forms are smooth (in Physarella an occasional spinous process occurs), and a careful examination shows that a majority of the threads are hollow and not solid as is usually stated. Where seeming solidity does occur, this is interpreted as due either to an actual collapse of the tube when in a plastic condition, or else in reality to the obscurity of the lumen owing to the fineness or opacity of the threads.

4. The columellar cavity in *Stemonitis fusca* pushes up from the base of the young fructification through the heaping protoplasm as a more or less cylindrical space. Progressive deposition of wall substance from the plasma membrane surrounding this space forms the resulting thick-walled, tubular columella.

5. The delicately anastomosing reticulations of the mature capillitial sac in *Stemonitis fusca* are formed subperipherally, just within a layer of peripheral protoplasm. In earlier stages, these reticulations are attached by a few fine capillitial threads to the fragile and evanescent sporangial wall.

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EXPLANATION OF PLATE XXIV

The drawings, except figure 15, were made with the aid of the camera lucida, and drawn at the level of the stage. Zeiss compensating oculars 2, 6, 8 and 12 were used, together with Zeiss 2 mm. apochromatic objectives NA 1.30 and 1.40.

FIGURES 1–15, *Physarella mirabilis*.

FIG. 1. The early appearance of capillitial spaces, and a young lime knot. The sporangial wall, from which the protoplasm has somewhat shrunken, is already rather thick. × 750.

FIG. 2. The capillitial thread, sporangial wall, and lime knot all have a common continuous boundary, which has in this instance attained an appreciable thickness. Shrinkage has occurred from the wall bounding the lime knot. × 1,000.

FIG. 3. A somewhat later stage, with still thicker wall about capillitium and lime knot. × 1,500.

FIG. 4. A preparation similar to figures 2 and 3, but showing shrunken lime knot and branching capillitial thread. × 1,000.

FIG. 5. A capillitial thread and sporangial wall again showing continuity of bounding membranes. × 1,500.

FIG. 6. Almost mature capillitial threads in which the lumen is not evident. × 1,000.

FIG. 7. A stage approaching maturity, in which a space is shown surrounding the capillitial thread. × 1,000.

FIG. 8. The cleavage furrows are limited by the capillitial threads, which appear in cross-section in the preparation, or else are cut somewhat obliquely. × 1,000.

FIG. 9. A preparation taken from a similar stage, showing a cleavage furrow following in part the hollow capillitial thread. × 1,000.

FIG. 10. Another similar, but somewhat older, stage of cleavage. × 1,000.

FIG. 11. Showing the attachment of the sporangial wall and a lime knot. × 750.

FIG. 12. A mature capillitial thread, containing two small lime knots; and a spore shown for comparison. From a mature, crushed sporangium. × 750.

FIG. 13. Another capillitial thread, showing branching and the occasional spine-like projections. × 1,000.

FIG. 14. Surface view of a portion of the wall of the sporangium, showing a large lime knot, small lime granules, and the yellow (shown as darker) pigment granules. × 1,000.

FIG. 15. Diagrammatic drawing of a mature sporangium, showing expanded base, hollow stalk, funnel-shaped sporangium, sporangial wall, and the radially arranged capillitium and lime knots. × about 20.

FIGURES 16–21, *Stemonitis fusca.*

FIG. 16. Upper portion of the space in which the columella is to be formed; showing thin columellar wall, protoplasmic inclusions, and the vacuolated area in the path of the rising axial cavity. × 250.

FIG. 17. Young stage in capillitium formation; showing a space in which no perceptible deposit of wall substance has as yet been made. × 1,000.

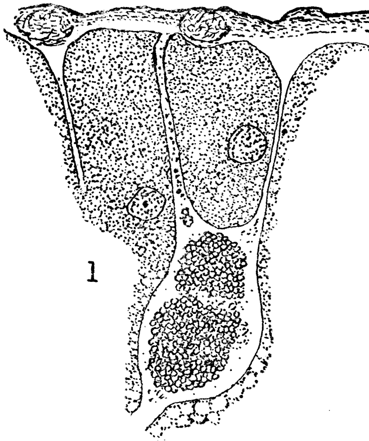
FIG. 18. Late stage in the development of the capillitium, showing attachment to the columella. × 750.

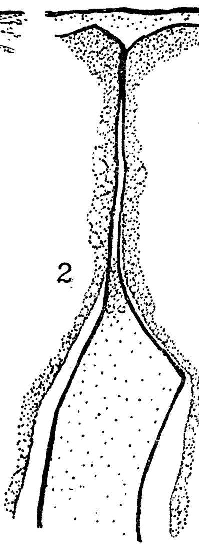
FIG. 19. Similar condition to figure 18, but showing columella in cross-section. × 750.

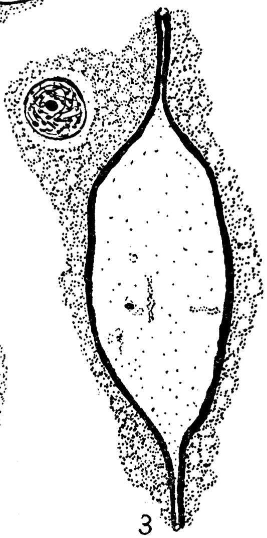
FIG. 20. A preparation from the peripheral portion of a sporangium, showing cleavage begun; together with a small fragment of the delicate, subperipheral, anastomosing, capillitial sac. × 750.

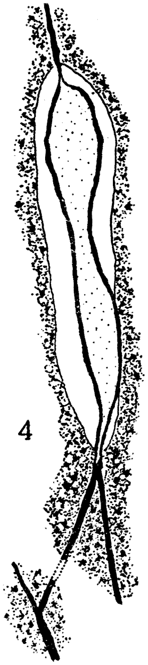
FIG. 21. A portion of the fragile, evanescent sporangial wall, showing a small capillitial thread attached. × 1,500.

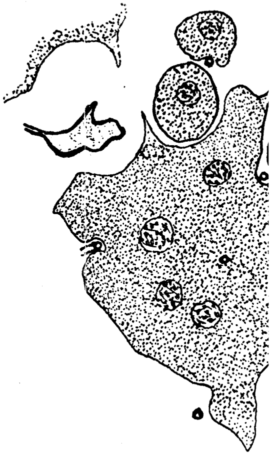
FIG. 22. Small portion of capillitium, from a mature sporangium, showing anastomosis, and the hollow character of one thread. × 1,500.

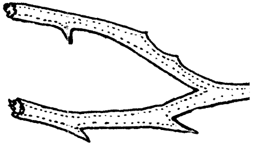


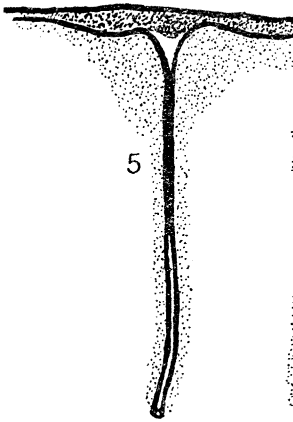


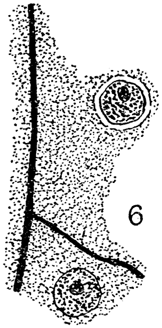


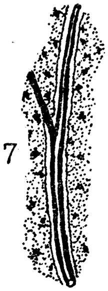


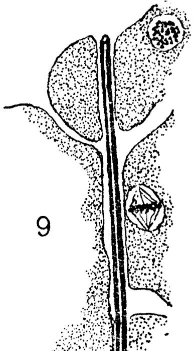


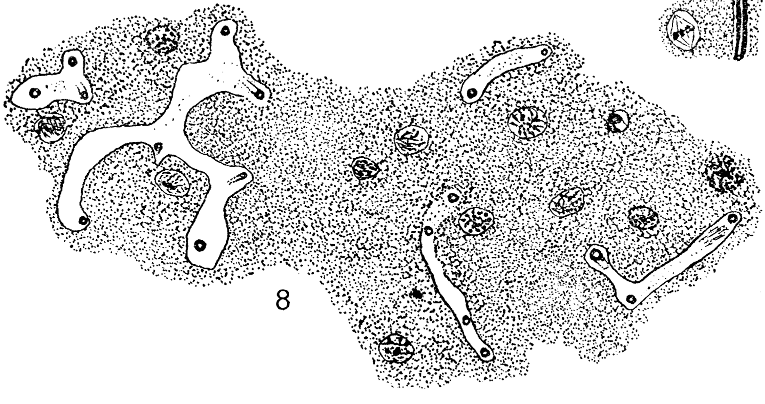


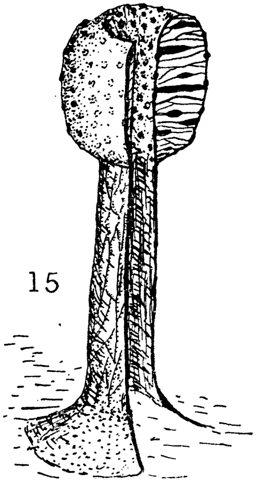


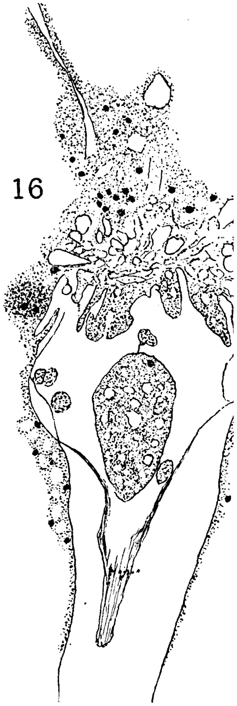












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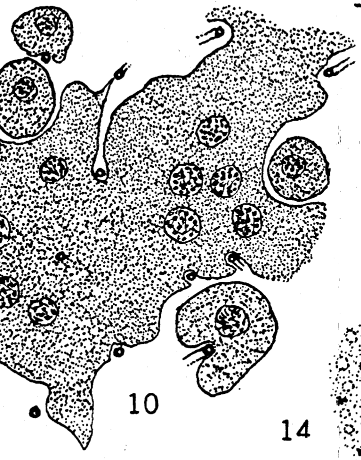

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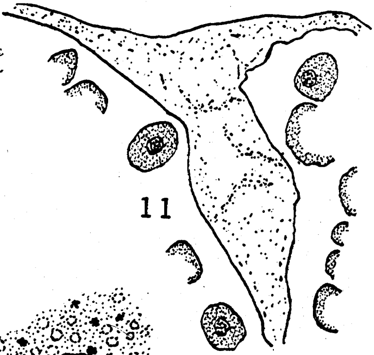

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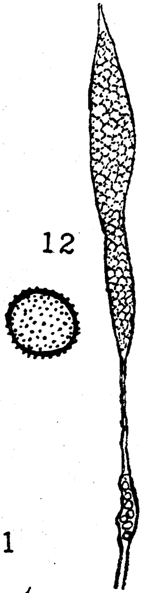

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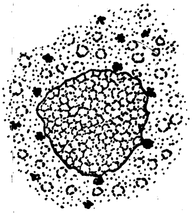

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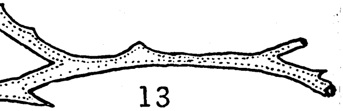

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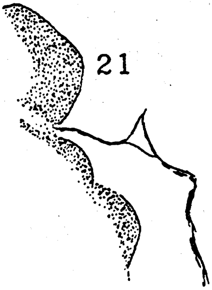

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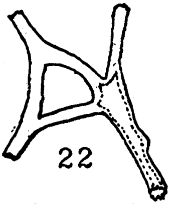

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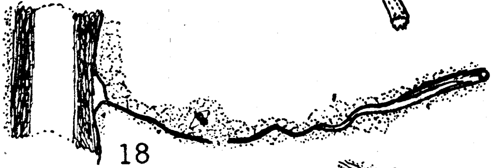

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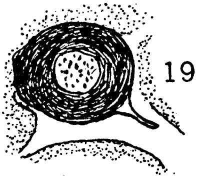

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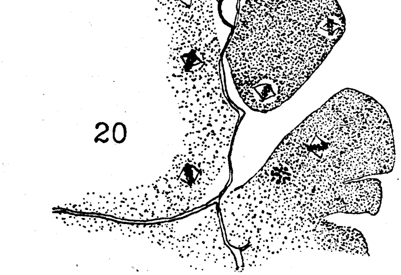

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